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Stalk dry mass and industrial yield of 16 varieties of sugar cane cultivated under water restriction

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Abstract

The great extension of the cultivated area, associated with the low water availability to supply the sugarcane demand in the periods of drought and the high evapotranspiration demand, requires varieties adapted to these specific conditions. The aim of this study was to assess 16 sugarcane varieties regarding the efficiency in water use (EWU) and in photosynthetically active radiation (PAR), cultivated under a water restriction, in the production of stalks dry matter, sugar and alcohol. The experiment was carried out in the Brazilian savannah biome, Goiás State, during the 2011/2012 crop year, in a randomized blocks design, with four repetitions. The treatments consisted of 16 varieties of sugarcane cultivated on a supply of only 50% of the water demand demanded by the crop. The EWU and EUPAR of the varieties were evaluated for the production of stalk dry mass (SDM), sugar and alcohol. During the crop cycle there was sufficient precipitation to supply the water demand of sugarcane; however, the irregular distribution of rainfall resulted in a water deficit of -697 mm during its cycle. The varieties IAC 91-1099, CTC-15, CTC-11, SP 86-0042 and IAC 87-3396 showed higher EWU and better photosynthetically active radiation for the production of stalks dry matter, sugar and alcohol. IACSP 94-2094 and CTC 09 varieties presented the same efficiency in industrial yield and lower dry matter yield than the five following varieties IAC 91-1099, CTC-15, CTC-11, SP 86-0042 and IAC 87-3396. Therefore, these last varieties are the most efficient in water use and photosynthetically active radiation aiming the stalks dry matter, sugar and alcohol production under water restriction.

Keywords: *Saccharum* spp.; Brazilian savannah; irrigation; bioenergy; evapotranspiration.
Abbrevaitions: EWU_efficiency in water use; EUPAR_efficiency in the use of photosynthetically active radiation; PAR_ photosynthetically active radiation; SDM_stalk dry mass.

Introduction

Brazil is the world's largest sugar cane producer, with an average yield of 72.54 Mg ha^{-1} cultivated in 10.24 million hectares during the 2017/18 crop year. São Paulo State is the holder of the largest cultivated area (51.72%), with an average yield, considering the last two harvests (2016/17 and 2017/18) of 77.05 Mg ha^{-1}, followed by the state of Goias, the second in area (10.81%), but with lower yield (73.86 Mg ha^{-1}), and by Minas Gerais, with 9.49% of the area and 76.73 Mg ha^{-1}. Regarding the technological quality of the sugarcane broth, the total recoverable sugar per megagram of stalk is 138.2 kg, leading to 37.87 Mg of sugar, and 27.76 billion liters of alcohol (Conab, 2018). The production of sugarcane dry matter, sugar and alcohol depends on several factors, such as the efficiency of the varieties to use the natural resources such as water and sunlight (Campos et al., 2014; Carvalho et al., 2015; Silva et al., 2017). Ferreira Junior et al. (2015) evaluating the efficiency in the use of photosynthetically active radiation for the dry matter production of the variety RB 98710, in tropical climate conditions, observed a linear response with a gain of 2.73 g MJ^{-1}. However, in tropical climate conditions with drought during the Brazilian autumn and winter (Gouvêa et al., 2009; Marin et al., 2012), water availability becomes the main limiting factor on crop growth and development (Marcari et al., 2015; Simões, et al., 2015; Anjos et al., 2017), requiring the selection of varieties adapted to low water availability. One of the techniques that have been used to solve or mitigate the lack of pluviometric precipitation in the fields of sugar cane production is the irrigation (Braido and Tommaselli, 2011; Oliveira et al., 2011). An increase in crop yield, when the water requeriments are achieved, is widely observed in literature (Dalri and Cruz, 2008; Battie-Laclau and Laclau, 2009; Silva et al., 2011; Oliveira et al., 2017). However, full irrigation is not common in sugarcane fields due to the extensive production areas of the crop (Marin and Nassif, 2013), requiring high investments and high water availability, making the survival irrigation a common practice. Therefore, the use of more efficient varieties in the use of water is a viable and economical alternative to minimize the yield losses caused by water deficit. Silva et al. (2011), studying sugarcane in the semiarid region with accumulated water deficit of -154.3 mm during the cycle, observed efficiency in water use in the variety RB 92579, with 9.49 kg of stalks, the production of 1.22 kg of sugar and 0.88 L of alcohol per m^{-3} of crop evapotranspiration and with 5.36 kg of stalks the production of 0.69 kg of sugar and 0.49 ml of alcohol per m^{-3}, being the water provided via irrigation or rainfall. Farias et al. (2008), without water restriction, observed water use efficiency for the variety SP 791011, resulting in 7.12 Kg of stalk production and 0.67 kg m^{-3} for sugar. However, Campos et al. (2014), evaluating the field and industrial production of sixteen sugarcane varieties in the Cerrado, with 50% of the crop evapotranspiration replacement, observed different efficiencies in the use of resources among varieties, being CTC9, CTC11, IAC87-3396, IAC91-1099 and SP86-0042 the ones that stood out. These studies show that different sugarcane varieties present variations for the efficiency in the use of environmental resources for plant growth and development. Thus, this study aimed to identify more adapted varieties to the climate conditions and management, which is essential for the profitability and sustainability of sugar-alcohol production. Thus, the objective of this study was to identify among 16 varieties, the most efficient sugarcane variety in the use of solar radiation and water, cultivated under water deficits in periods of prolonged drought and dry season, in the production of stalks dry matter, sugar and alcohol.

Results and Discussion

Analysis of the meteorological influence on sugarcane

The mean temperature varied from 23.3ºC and 25.6ºC (Fig 1A), in the range considered favorable for the sugarcane growth and development, which is 20°C ≤ Tar ≤ 30°C, mainly during the tillering phase (Argeton, 2006). Appropriate conditions were observed regarding the relative air humidity (RH%), which on average was between 55% and 70%. The photosynthetic active radiation (PAR) accumulated in the month was 221 MJ m^{-2} $month^{-1}$, ie 7.9 MJ m^{-2} day^{-1} (Fig 1A). According to Ferreira Júnior (2015), the sugarcane, when under suitable conditions of humidity and temperature, presents yield gains with the increase of PAR. These varieties present a C4 photosynthetic cycle, with high efficiency of conversion of radiant energy to chemical energy, when submitted to conditions of high air temperature and intense solar radiation, associated to the high water availability in the soil. Therefore, by keeping the soil moisture in the water range readily available for the variety, it is possible to favor the genetic potential of the crop regarding the yield.

During the sugarcane crop cycle (396 days) a total rainfall of 1209.3 mm was observed (Fig. 1B), being a volume considered satisfactory (>1000 mm $cycle^{-1}$) (Marin and Nassif, 2013). This pluviometric regime was above the crop potential evapotranspiration (ETc = 1029.6 mm). However, its irregular distribution resulted in periods of water deficit (DEF) (Fig 1C). Between May, 2011 and September, 2011 the accumulated DEF observed was -535 mm and from April, 2012 to May, 2012, -92 mm. During the whole crop cycle, the DEF achieved -697 mm (Figure 1C), resulting in no water storage in the soil (Fig 1C). It was also observed that the longest uninterrupted water deficit occurred between June, 2011 and September, 2011 (DEFac = -467.13 mm), followed by the period from May, 2012 to August, 2012 (DEFac = -290.47 mm), both resulting in relative evapotranspiration equal to zero (ETR/ETc = 0.0) (Fig 1D). These data demonstrate the importance of irrigation in this region (even if partial) and reinforces the need of a more adapter sugarcane variety to these climatic conditions of cultivation. These periods of drought damage the sprouting and vegetative growth stages of sugarcane in conditions of no irrigation (Oliveira et al., 2011; Campos et al., 2014). On the other hand, it allows an improvement in the product quality, when the water deficit is observed during the maturation stage, explained by the fact that the crop need a period of stress for the conversion of starch into sucrose and fructose, which are the main substrate for the sugar and alcohol production (Khan et al., 2011).

Efficiency in the use of water and photosynthetically active radiation of cane varities

According to the statistical results, it was possible to observe significant differences between the varieties regarding the water use efficiency (EWU) and radiation (PAR) evaluating the stalk dry matter and the industrial production of sugar and alcohol (Table 2). The water use efficiencies of the varieties for the production of stalk dry mass (EWU_{SDM}), sugar (EWU_{SUGAR}) and hydrated alcohol ($EWU_{ALCOHOL}$) were respectively 4.63 kg of SDM m^{-3} H_2O, 2.06 kg of sugar m^{-3} H_2O, and 1.27 L of alcohol m^{-3} H_2O. The efficiencies in radiation use were 1.18 g of MSC, 0.53 g of sugar and 0.32 mL of alcohol MJ^{-1} PAR, respectively (Table 2). The largest EWU in relation to PAR for sugarcane varieties may be due to the typical water restriction in the sugarcane production areas of the middle-west region of Brazil, associated to the abundant solar radiation throughout the year (Fig 1). These conditions lead plants to optimize the use of water stored in the soil from the opening and closing stomata control (Inman-Banber and Smith, 2005; Duarte, 2010; Khan et al., 2011). Due to the high PAR (3188.1 MJ) accumulated during the crop cycle, the values of sugarcane production per unit of PAR may seem low. However, when is performed the sum of the values during the crop cycle, they reached values of stalk yield, in Mg ha^{-1}, of 115 (minimum var. RB 92-579), 138 (medium) and 155 (maximum, var. CTC 11). The production in kg of TRS per Mg of stalk ranged from 106 to 138 (Table 1), above the yield of the São Paulo State (76 Mg ha^{-1}), which is the largest national producer (Conab, 2018). These values of yield among sugarcane varieties corroborate those found by Vieira et al. (2012), who observed values in the order of 110 to 147 kg of ATR per Mg of stalk and Campos et al. (2014), with 106 to 146 kg of ATR per Mg of stalk, and 108 to 170 Mg ha^{-1} of stalk. Both authors associated the variation in crop yield with their different performance in using natural resources such as water and light. The higher efficiency was presented by the variety IAC-91-1099 (5.51 kg of SDM; 2.48 kg of sugar and 1.53 L of alcohol per m^3 of H_2O used during the crop cycle). The variety with the lower efficiency was CTC-18 (3.83 kg MSC m^{-3} H_2O). The variety RB-92-579 presented higher EWU for sugar production (1.22 kg m^{-3} H_2O) and alcohol (0.88 L m^{-3} H_2O). According to the statistical evaluations (mean test ($p>0.05$ – Table 2) and from the grouping analysis of the varieties (Fig 2)), it is possible to affirm that the most efficient varieties for all evaluated variables were IAC-91-1099, CTC-15, CTC-11, SP-86-0042 and IAC-87-3396 (Group 1). However, the varieties CTC - 02, IACSP 94-2094 and CTC 09 from group 3, although not efficient in dry matter

Table 1. Stalk yield (Y_{TCH}), stalk humidity (U_{TCH}) and of stalk dry mass (SDM), total recoverable sugars (TRS), very high purity sugar - VHP yield (Y_{SUG}) and hydrated alcohol yield (Y_{ALC}) of sugarcane varieties cultivated in Goianésia, GO, Brazil, 2011/2012 crop year.

Varieties	Y_{TCH}	U_{TCH}	SDM	TRS	Y_{SUG}	Y_{ALC}
	Mg ha^{-1}	%	Mg ha^{-1}	kg Mg^{-1}	kg ha^{-1}	L ha^{-1}
IAC 91-1099	155.51a*	72.89ab	41.99a	127.90bc	19.92a	11.99a
CTC – 15	154.86a	72.36ab	41.92a	124.50cd	18.44ab	11.40ab
CTC – 11	153.89a	72.87ab	41.66a	131.78b	19.40a	11.99a
SP 86-0042	152.64ab	73.92ab	41.32a	127.72c	18.65ab	11.53ab
IAC 87-3396	152.50ab	72.64ab	41.28a	127.12c	18.55abc	11.46abc
RB 92-579	150.83ab	75.96a	40.83ab	106.14f	15.32 abc	9.47abc
CTC - 02	142.36ab	72.93ab	38.54abc	122.90de	16.74abc	10.34abc
RB 86-7515	137.78bc	74.21ab	37.30bcd	121.15de	15.97abc	9.87abc
CTC - 04	137.36bc	75.90a	37.18bcd	118.35e	15.55abc	9.61abc
IACSP 94-2094	136.53bc	72.10ab	36.96cd	131.46b	17.17abc	10.61abc
IACSP 94-3046	130.28cd	74.26ab	35.27bcd	128.24bc	15.98abc	9.88abc
CTC – 09	126.67d	70.56b	34.29d	146.12a	17.71abc	10.94abc
RB 96-6928	125.56cd	72.76ab	33.99d	127.51c	15.32abc	9.47abc
IACSP 95-5000	122.22cde	72.85ab	33.09d	130.84bc	15.30abc	9.46abc
IACSP 94-2101	117.92de	74.14ab	31.92d	123.20d	13.90bc	8.59bc
CTC - 18	115.00e	73.59ab	31.13d	123.59d	13.60c	8.40c
Mean	138.06	73.36	37.37	126.11	16.63	10.28
CV (%)	5.58	2.39	6.25	7.65	8.04	8.09

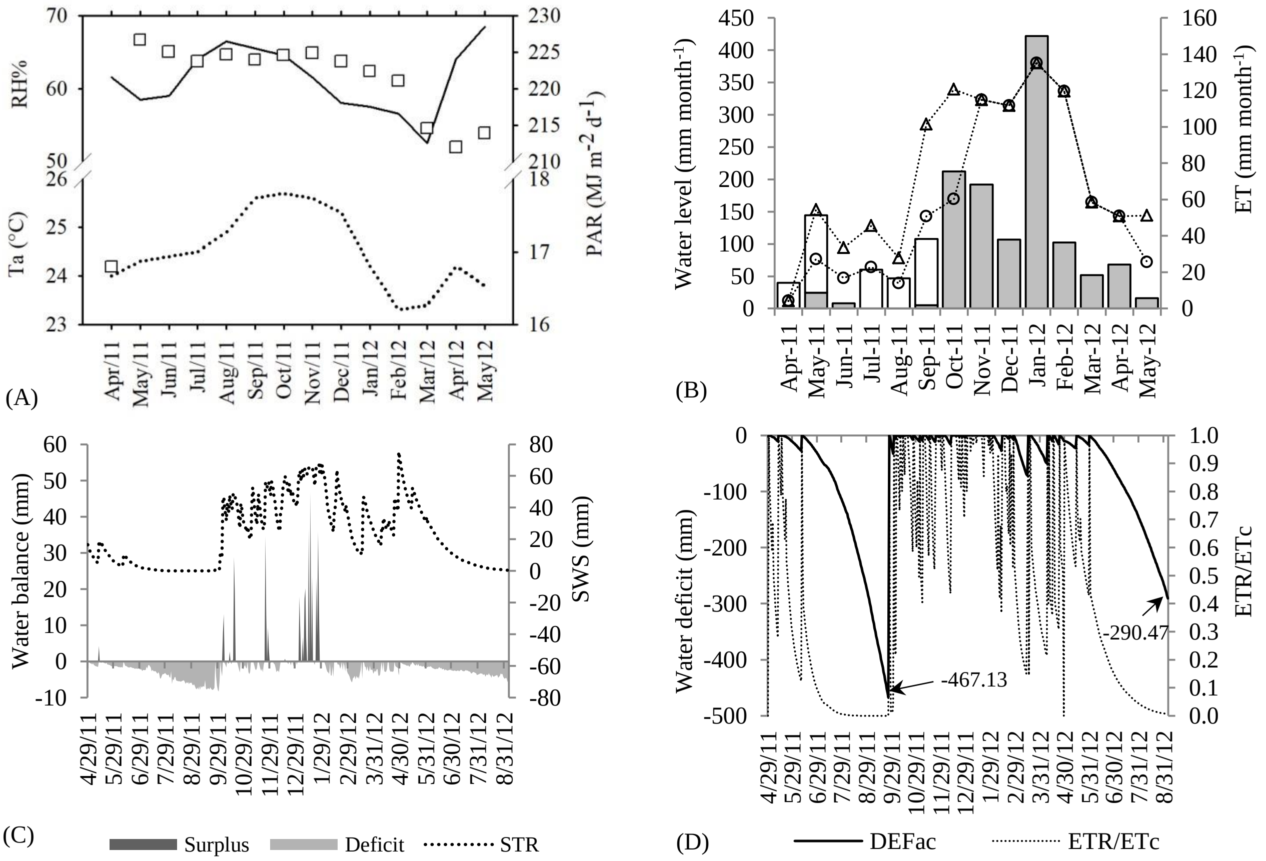

Fig 1. Meteorological parameters throughout the sugarcane cycle - A: Air temperature (Ta, °C, dotted line), relative humidity (RH%, full line), photosynthetically active radiation (PAR, MJ m^{-2} d^{-1}, □); B: Rainfall (mm month^{-1}, gray columns), irrigation level (mm month^{-1}, white columns), crop evapotranspiration (ETc, mm month^{-1}, Δ) and crop evapotranspiration at 50% (ETc 50%, mm month^{-1}, ○); C: water balance and soil water storage (SWT, mm); D: accumulated water deficit (DEFac, mm) and relative evapotranspiration (ETR/ETc). Sugarcane cultivated in Goianésia, GO, Brazil, 2011/2012 crop year.

Table 2. Efficiency in water use (EWU) and efficiency in water use of photossyntetically active radiation (EUPAR) in stalk dry mass yield (SDM), very high polarization - VHP sugar production (S) and hydrated alcohol production (A) from sugarcane varieties harvested 396 days after planting. Goianésia, GO, Brazil, 2011/2012.

Varieties	EWU_{DMS} (kg m^{-3})	$EUPAR_{DMS}$ (g MJ^{-1})	EWU_{S} (kg m^{-3})	$EUPAR_{S}$ (g MJ^{-1})	EWU_{A} (L MJ^{-1})	$EUPAR_{A}$ (mL MJ^{-1})
IAC 91-1099	5.51 a*	1.40 a	2.48 a	0.63 a	1.53 a	0.39 a
CTC – 15	5.16 ab	1.31 ab	2.27 a	0.58 a	1.40 a	0.36 a
CTC – 11	5.13 ab	1.31 ab	2.39 ab	0.61 ab	1.48 ab	0.38 ab
SP 86-0042	5.09 ab	1.30 ab	2.30 ab	0.58 ab	1.42 ab	0.36 ab
IAC 87-3396	5.08 ab	1.29 ab	2.28 abc	0.58 abc	1.41 abc	0.36 abc
RB 92-579	5.03 abc	1.28 abc	1.89 abc	0.48 abc	1.17 abc	0.30 abc
CTC - 02	4.74 abcd	1.21 abcd	2.06 abc	0.53 abc	1.27 abc	0.32 abc
RB 86-7515	4.59 abcd	1.17 abcd	1.97 abc	0.50 abc	1.21 abc	0.31 abc
CTC - 04	4.58 abcd	1.17 abcd	1.91 abc	0.49 abc	1.18 abc	0.30 abc
IACSP 94-2094	4.55 abcd	1.16 abcd	2.11 abc	0.54 abc	1.31 abc	0.33 abc
IACSP 94-3046	4.34 cbd	1.11 bcd	1.97 abc	0.50 abc	1.22 abc	0.31 abc
CTC – 09	4.22 cbd	1.08 bcd	2.18 abc	0.56 abc	1.35 abc	0.34 abc
RB 96-6928	4.18 cbd	1.07 bcd	1.89 abc	0.48 abc	1.17 abc	0.30 abc
IACSP 95-5000	4.07 bd	1.04 cd	1.88 abc	0.48 abc	1.16 abc	0.30 abc
IACSP 94-2101	3.93 d	1.00 d	1.71 bc	0.44 bc	1.06 bc	0.27 bc
CTC - 18	3.83 d	0.98 d	1.67 c	0.43 c	1.03 c	0.26 c
Mean	4.63	1.18	2.06	0.53	1.27	0.32
SMD	0.47	0.25	0.29	0.15	0.18	0.15

*Means with the same letter in the column are not different, according to Tukey´s test at 5% of error probability. MSD = minimum significant difference.

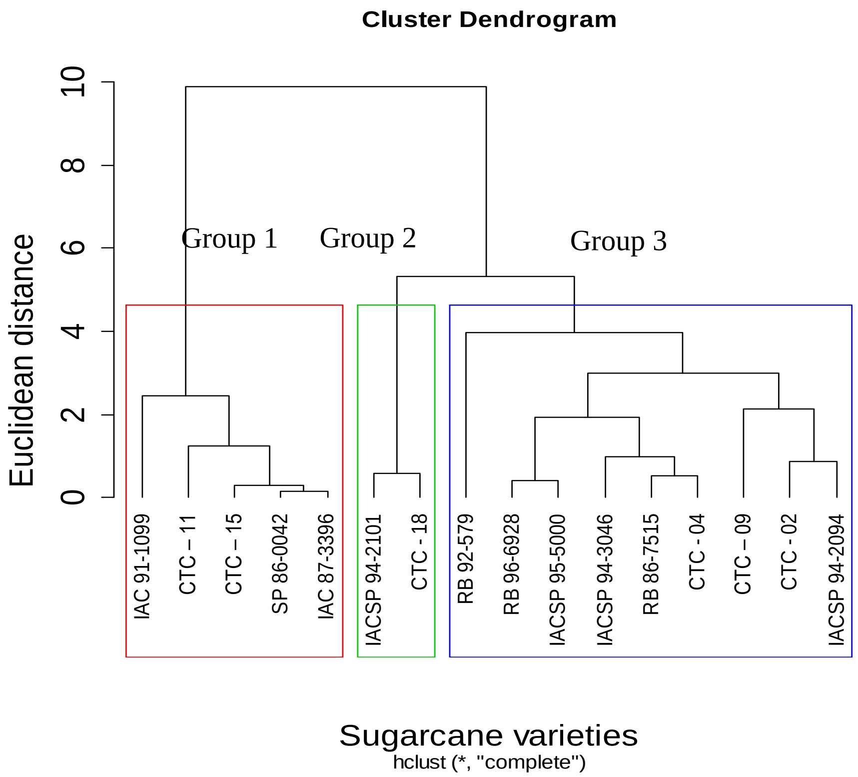

Fig 2. Cluster analysis of sugarcane varieties according to the efficiency in water and radiation use, stalk dry matter, sugar and alcohol production. Note: the groups were formed from half of the Euclidean distance. *Group 1: red line; Group 2: green line; Group 3: blue line.

production, do not differ from the group 1, regarding the EWU and PAR for sugar and alcohol production. From the same evaluation (Table 2), it was observed that RB 92-579 presents EWU and radiation for the stalk production similar to those from group 1, but with lower efficiecy on sugar and alcohol productivity.

The IACSP 94-2101 and CTC-18 varieties, under the edaphoclimatic conditions of the cerrado of the Goias State, with a water supply of 50% of the crop demand, were the least efficient in both water and sunlight use for sugar, sugar and alcohol production, being grouped in group 2 (Fig 2), by cluster analysis. This result wss corroborated by Tukey's mean comparison test (p> 0.05). Thus, the water restriction in plant tissues, due to the loss of gaseous exchanges and the lower capacity of water extraction by the roots, had a deleterious effect on the production of stem dry matter and technological quality, with differences in the 16 sugarcane varieties evaluated. The water restriction impacts the processes related to turgescence, stomatal closure, photosynthesis, respiration and, consequently, plant growth and development patterns differently between plants (Shabani et al., 2013). In addition, other negative effects of water deficit are found in IAC variety (IAC-SP-94-2094, IAC-SP-96-2042, IAC-SP-791011) and RB (RB-72454, RB-98710, RB 92579), such as: reduction of stomatal conductance at different stages of development, decrease in transpiration and photosynthetic activity, lower plant size, productivity decrease, and lower water efficiency (Gonçalves et al., 2010; Machado et al., 2009).

Materials and Methods

Plant materials

The varieties used in this study were chosen because they are currently the most cultivated varieties in Brazil, according to the Ridesa-Brasil senses. In the sugar-alcohol plant where the experiment was installed the varietal sense showed that 10% of the cultivated areas with the variety RB86-7515, 9% with CTC-04, 7% with IAC91-1099, 7% with CTC-15, 5% with IAC87 -3396, 5% with CTC-18, 4% with SP84-1431, 3% with SP86-0042, 3% with SP79-1011, 3% with CTC-02, 2% with IACSP95-5000, 2% with IACSP94- 2101, 1% with CTC-09, 1% with CT94-3166, 1% with SP83-5073, 1% with SP83-2847, 35% with others. (Campos et al., 2014).

Experimental location, soil preparation and planting

The experiment was carried out in a yellow-red dystrophic latosol (Embrapa, 2006), at the Jalles Machado Farm/ Industry in the municipality of Goianésia-GO, Brazil (15º 12' S, 48º 59' W and 580 m altitude). According to Köppen, the climate of the region is classified as Aw (Tropical Savannah), with dry winter and rainy summer. The average annual rainfall is 1,540 mm, with a well-defined water deficit period, from May to October.

Before the experiment installation, the area contained degraded pasture, with predominance of brachiaria grass (*Urochloa decumbens*). Six months prior to the area preparation, deformed soil samples were collected for chemical analysis in the layers of 0.0-0.25m and 0.25-0.50 m. Undisturbed samples were collected for soil physic-hydric analysis: field capacity - Fc (21.36%), permanent wilting point - PWP (13%) and soil density (1.43 g cm^{-3}) in de 0.0-0.30m and 0.30-0.60 m depths (the properties did not differ between the two soil depths). The soil was corrected with dolomitic limestone, increasing the base saturation to 50%. Agricultural gypsum (2,250 kg ha^{-1}) and natural phosphate - P_2O_5 (100 kg ha^{-1}) were applied.

During the soil preparation, a heavy harrowing was carried out for the incorporation of soil correctives. Subsequently, an intermediate harrowing was performed the incorporation of natural phosphate clods breaking. In soil leveling, light harrowing was used before planting.

The sugarcane planting was carried out manually, on 04/29/2011, with stalks containing three vegetative buds. At the bottom of the planting groove (≈0.35 m) 115 kg/ha of P_2O_5 were distributed (using triple superphosphate). Then, the furrows were covered and the insecticide fipronil 800 WG (0.050 kg ha^{-1} p.c.) was applied to prevent termite attack. Some crop treatments were carried out during the sugarcane cycle, such as the systematization between lines, cover fertilization (05-00-12 + 0.3% B + 0.3% Zn at the dose of 1,200 kg ha^{-1}) and pre-emergence weed control.

To stimulate the plants sprouting, 40 mm of irrigation was applied to achieve the soil field capacity. Other irrigations were carried out to supply half of the evapotranspiration between irrigations.

Experimental design

A completed randomized block design with four replicates was used. The treatments consisted of 16 sugarcane varieties: CTC2, CTC4, CTC9, CTC11, CTC15, CTC15, CTC18, IAC87-3396, IAC91-1099, IACSP94-3046, IACSP94-2094, IACSP94-2101, IACSP95-5000, RB857515, RB92579, RB966928 and SP86-0042. The experimental plots consisted of four lines with 15 m in length each, spaced at 1.5 m, with 18 gems m^{-1} (90 m²).

Irrigation management

Irrigation management was performed based on the sugarcane demand, given by the crop potential evapotranspiration (ETc, mm), which is determined by the potential evapotranspiration (ETP, mm) and the crop coefficient (Kc). The ETP was estimated by the Penman-Monteith-FAO equation (Allen et al., 1998), and the meteorological data were obtained from an automatic meteorological station at the Jalles Machado industry, located close to the experimental area (≈3 km). Kc values of 0.5; 0.8; 1.25 and 0.8 were used for the respective crop stages: germination (30 days), development (140 days), full development (145 days) and maturation (81 days) (Dalri and Cruz, 2008).

The irrigation depth was calculated using a sequential water balance, according to Thornthwaite and Mather (1955). The available water capacity (AWC, mm) was calculated by Eq. [1]:

$$AWC = 1000 * (\theta_{CC} - \theta_{PWP}) * Ze$$

Where θ_{FC} is the water content in the field capacity (0.21 $m^3 m^{-3}$), θ_{PWP} is the water content in the permanent wilting point (0.13 $m^3 m^{-3}$), and Ze is the effective root depth (m), with a range of 0.2 m at 0.90 m, throughout the crop cycle. Rainfall and irrigation were considered as water inputs in the system, and ETc as an output. The irrigation was performed as supplementary and with deficit, supplying only 50% of the crop water requirement (50% of ETc). In the months with water deficit during the crop cycle, irrigation of 369.81 mm was applied.

The irrigation was performed using a self-propelled sprinkler model Turbomaq 140/GSV/350-4RII, implemented with irrigation bar model 48/54 manufactured by the company "Irriga Brasil", with a range of application of 54 meters, with a maximum free bar to the soil ranging from 1.00m to 4.00m. The spray sprinkler LDN® with Senninger #21 nozzles (flow 109.90 L h^{-1} and a service pressure of 36 mca) was used with a Senninger 20 psi pressure regulator. The application efficiency was 83% (verified in the field).

Plant management and assessments

The study was conducted during the cane-plant cycle, harvested at 396 days after planting (May 29, 2012), using mechanized harvesting.

After cutting the sugarcane, the stalk yield (Y_{TCH}), was evaluated (Table 1), obtained by weighing the stalk and dividing the value by the area of the plot, with the result extrapolated to the area of one hectare, which was expressed in Mg ha^{-1}. The mass of 10 green stalks of each plot (digital suspended scale) was carried out, with the following technological evaluations: stalk humidity (U_{TCH}, %) and total recoverable sugars (TRS) in kg ha^{-1}. From these data, the yield of VHP Sugar with 99.3°Z and 0.15% moisture (Y_{SUGAR}), in kg ha^{-1}, and hydrated alcohol ($Y_{ALCOHOL}$), in L ha^{-1}, were estimated according to the standards N-133 and N-135, respectively (Consecana, 2006). The yield in stalk dry mass (Y_{SDM}) in Mg ha^{-1} was obtained by the difference between the stalk yield of each plot and its percentage humidity (U_{TCH}, %):

$$U\% = \left(\frac{W_M - D_M}{D_M}\right) * 100$$

Being WM the wet mass (g) and DM dry matter (g). The sugarcane broth (cane wet mass) was extracted using a hydraulic press, with a constant pressure of 250 kgf cm^{-2} on the sample (500 grams), crushed and mechanically homogenized during one minute.

The analysis of water use efficiency (EWU) and photosynthetically active radiation (PAR) of the sugarcane varieties was carried out, respectively, by the relationship between Y_{SDM} (Mg ha^{-1}), Y_{SUGAR} (kg ha^{-1}), and $Y_{ALCOHOL}$ (L ha^{-1}) and the accumulated values of ETc50% and PAR (photosynthetically active radiation) was estimated as 43% of the incident global radiation (Ferreira Júnior et al., 2015).

Statistical analysis

Data were submitted to variance analysis using the F test and means compared by the Tukey´s test at 5% of error probability. The R software version 3.4.4. was used and cluster analysis was performed for all studied varieties according to their efficiency variables of water and radiation use in the production of stalks dry mass, sugar content and alcohol, complementing the results obtained by the Tukey´s test.

Conclusion

Under conditions of controlled water deficit, it is recommended the varieties IAC 91-1099, CTC-15, CTC-11, SP 86-0042 and IAC 87-3396.

On the other hand, the varieties IACSP-94-2101 and CTC-18 are not recommended for conditions of controlled water deficit, under the edaphoclimatic conditions of the 'Cerrado' (Brazilian savannah) of the State of Goias.

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